MODIS Semi-Annual Report (JULY 1996 - December 1996)

Bo-Cai Gao, Warren Wiscombe, Michael Mishchenko,
Wei Han, Allen Chu, and Anthony Davis

This reports covers the MODIS **cirrus characterization and correction** algorithm.

Main topics addressed in this time period:

1. **Sub-contracting** from Naval Research Laboratory (NRL) to State University of New York at Stony Brook (SUNY) *(Gao)* - The funds to the co-investigator, Michael Mishchenko, have to be transferred to SUNY through a sub-contract between NRL and SUNY. The setting up of such a sub-contract took quite a bit of time and efforts from Gao. The sub-contract was finally set-up just before FY97. If the sub-contract was set up after October 1, 1996, NRL would impose a service charge for setting up the contract. Now NRL impose a service charge of $685 per fund transfer from NRL to SUNY.

2. **New hiring** - Through recommendations from friends and a regular job interview but no formal job advertisement, *Wei Han*, from University of Alaska, was hired to help with radiative transfer modeling and algorithm development. She started to work inside NRL through SFA, a contracting company, in September of 1996.

3. **Ice particle phase function calculations -** *Mishchenko* modified his T-matrix method for calculating phase functions of spheroids with smooth surfaces. The modified T-matrix procedure has no abnormal sensitivity to weak or zero absorption. It allows efficient computations of scattering for particles with size parameters of 100 or greater. The algorithm developed by *Andrew Macke* for calculating phase functions of non-spherical ice particles with edges (such as hexagonal particles) is also available. At present, *Mishchenko* is using the new T-matrix scheme as well as the standard ray optics approximation (for large particles) in massive computations of the scattering and radiative characteristics of polydispersions of randomly oriented ice crystals of various shapes at MODIS wavelengths. Professor K.-N. Liou's research group at University of Utah is currently helping Mike King's group with ice particle phase function calculations. Liou's group also provided sample phase functions to *Gao* and expressed interests in further help in the future.

4. **Radiative transfer modeling** *(Wei Han, Gao, and Davis)* -

a. Expansion of phase function - Ice particle phase functions vary rapidly with scattering angle. The phase functions need to be expanded into sets of Legendre polynomials. The expansion coefficients can then be used in radiative transfer codes (such as DISORT of Stamnes et al.). After numerous tries, we found that about 10,000 terms are needed for expansions of ice particle phase functions for visible wavelengths with no absorption, and about 2,000 terms are needed for wavelengths near 1.64 and 2.1 μm where ice absorption occur. There are very good agreements between the original phase functions and re-constructed phase functions from the expansion coefficients. The errors between 3 degrees and 178 degrees of scattering angles are less than 0.5%.

b. Improving DISORT- Originally, the DISORT (Stamnes et al.) radiative transfer code implemented only the Lambertian bottom surface boundary conditions. Working together with Si-Chee Tsay and North Larsen at NASA GSFC, Wei Han has implemented bidirectional-reflecting bottom surface boundary conditions to DISORT. Using the Legendre expansion coefficients and the DISORT (with Nakajima's improvement), it is now possible to model and to characterize spectral reflectance properties of cirrus cloud over various land surfaces, and to conduct sensitivity studies as well.

c. Monte-Carlo Code - DISORT does not handle Fresnel reflection from bottom ocean surfaces, particularly under windy conditions with ocean waves. A Monte Carlo code can, in principle, handle the situation of one layer of cirrus clouds in the atmosphere with bottom oceanic surfaces. Anthony Davis, who works for Warren Wiscombe, has outlined a plan to update a Monte Carlo code for such simulations. Such an algorithm will be useful for validation of our empirical thin cirrus removal algorithm (as outlined in our proposal). So far, Anthony hasn't done any actual coding yet. In order to ensure progress is made with MODIS cirrus project, Warren Wiscombe will likely bring Bill Ridgway in for help with modeling and algorithm development.

5. **Data Analysis** *(Wei Han, Gao,)* - We have made a few case studies on cirrus detection and correction over ocean, vegetation, and the Arctic tundra through analysis of AVIRIS and MAS data. Our empirical cirrus correction method seems to work well, based solely on visual inspections. Although several people were alarmed when seeing weak surface features in water vapor channels near 1.38 and 1.88 μm under the very dry arctic conditions, we found from MAS data that the 1.88 μm channel is still the best channel to detect thin clouds over arctic tundra (because of absorption by water vapor between clouds and the surface), while the IR emission channels and visible channels fail completely in detecting any clouds.

6. **Algorithm Development** *(Han, Gao,, Chu)* - With the help of Allen Chu (who is with Yoram Kaufman's group and who is handling I/O interfaces for MODIS near-IR water vapor algorithm), we have developed an I/O interface for the

MODIS cirrus correction algorithm. Because the MODIS Tool Kit and HDF format changes, we decided to delay scientific coding until the platform becomes stable. We also made file specifications for the cirrus correction algorithm.

Plans for the next 6 month:

1. Speed up the development of empirical cirrus removing algorithm and aircraft contrail detection algorithm, after the platform for software development becomes stable. We will meet the V2 delivery deadline.

2. Continue analysis of AVIRIS and MAS data from different field campaigns.

3. More development on radiative transfer programs and sensitivity studies if time permitting.

4. Write the ATBD for the cirrus correction algorithm (based on our MODIS cirrus proposal).